Understanding modulation of marine heat waves by winds in eastern boundary upwelling systems

by using long-term satellite and in-situ physical oceanographic and meteorological observations

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USGCRP Observations Interagency Working Group
"Earth Observations in a Changing Climate" Webinar
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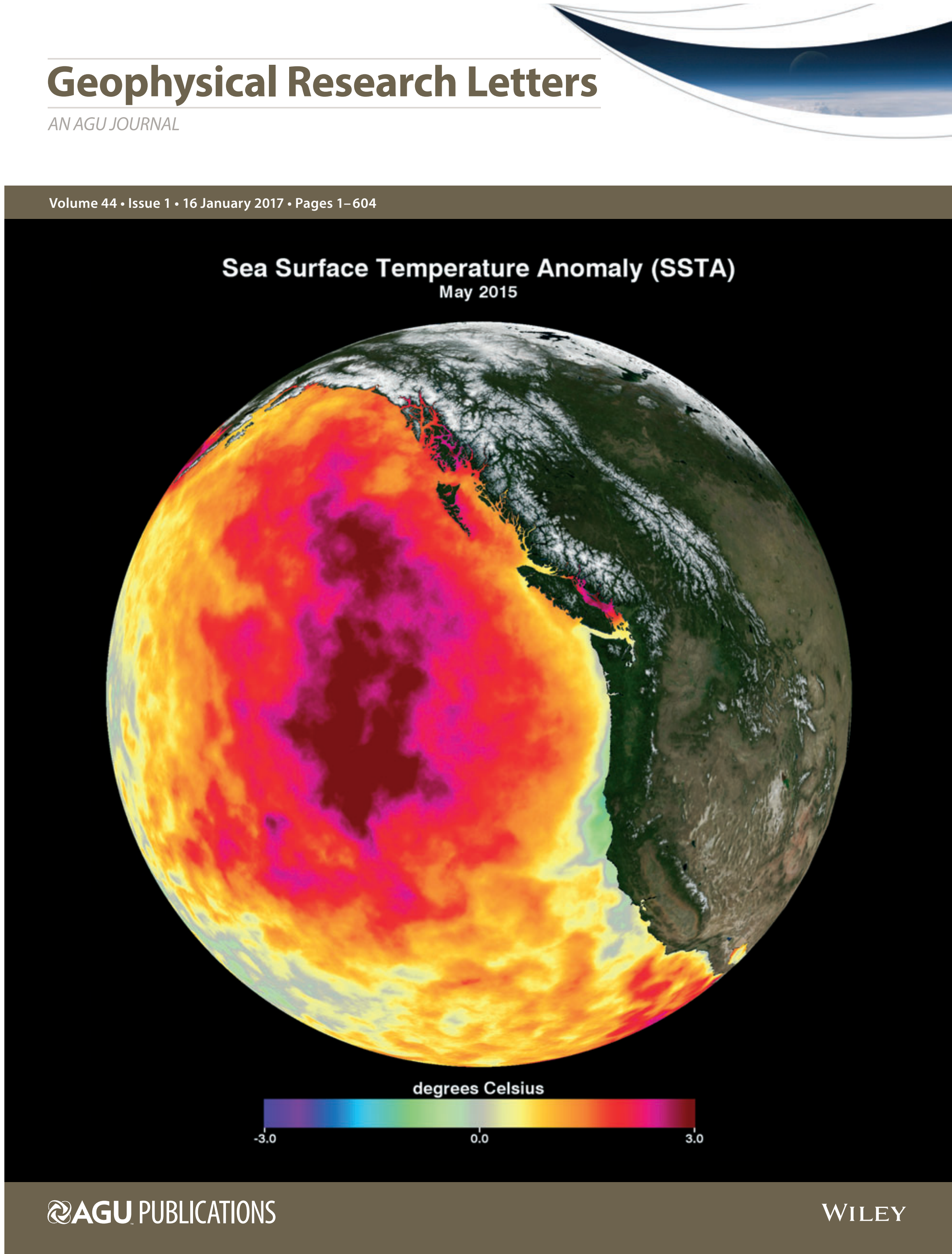


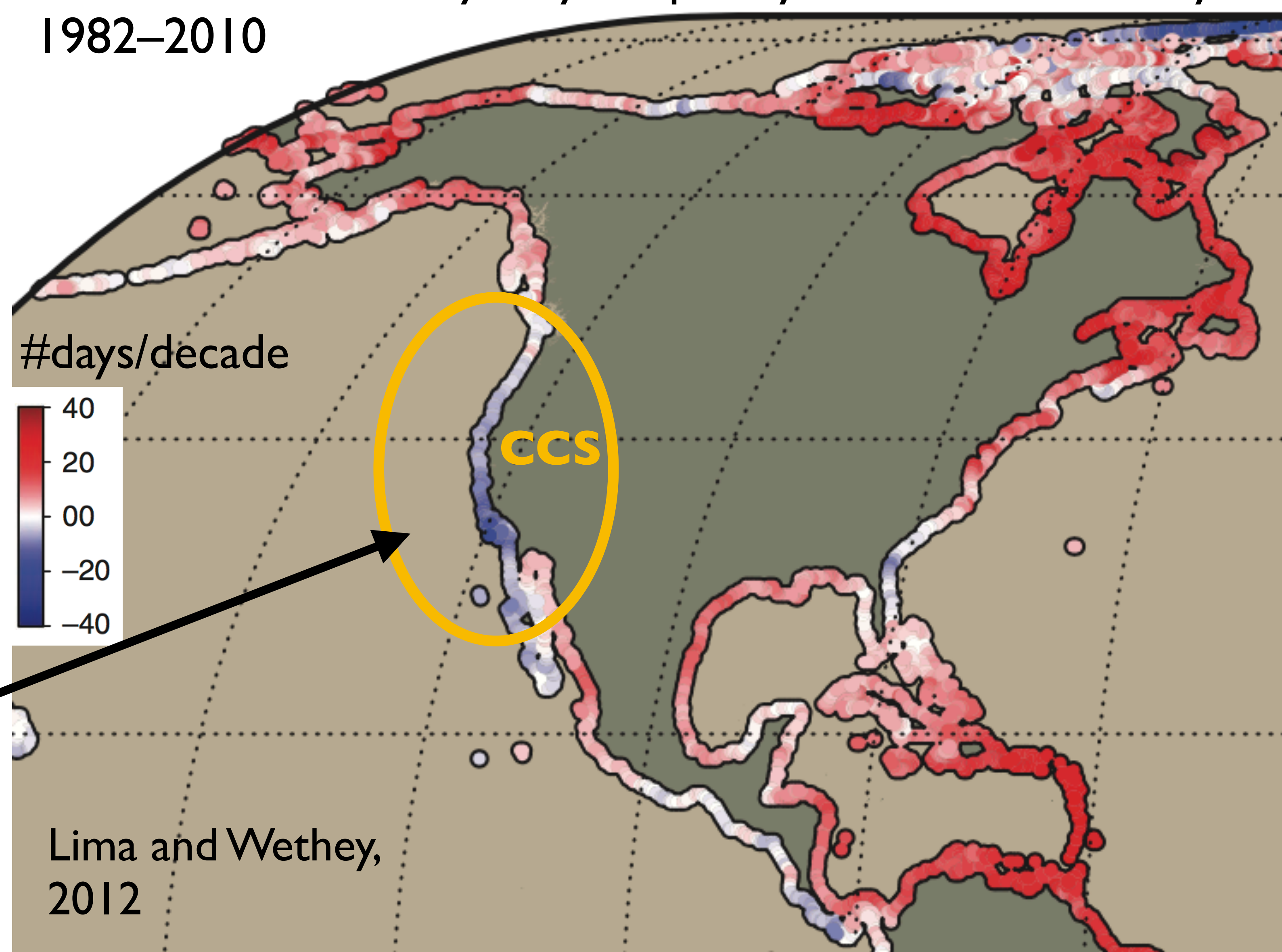
Gentemann, Fewings, and García-Reyes, 2017

Coastal areas show strong spatial variations in MHWs

- frequency (Scannell et al., 2016)
- intensity and duration (Oliver et al., 2018)
- trend in # of extreme hot days (Lima and Wethey, 2012)
- physical forcing mechanisms (Holbrook et al., 2019)

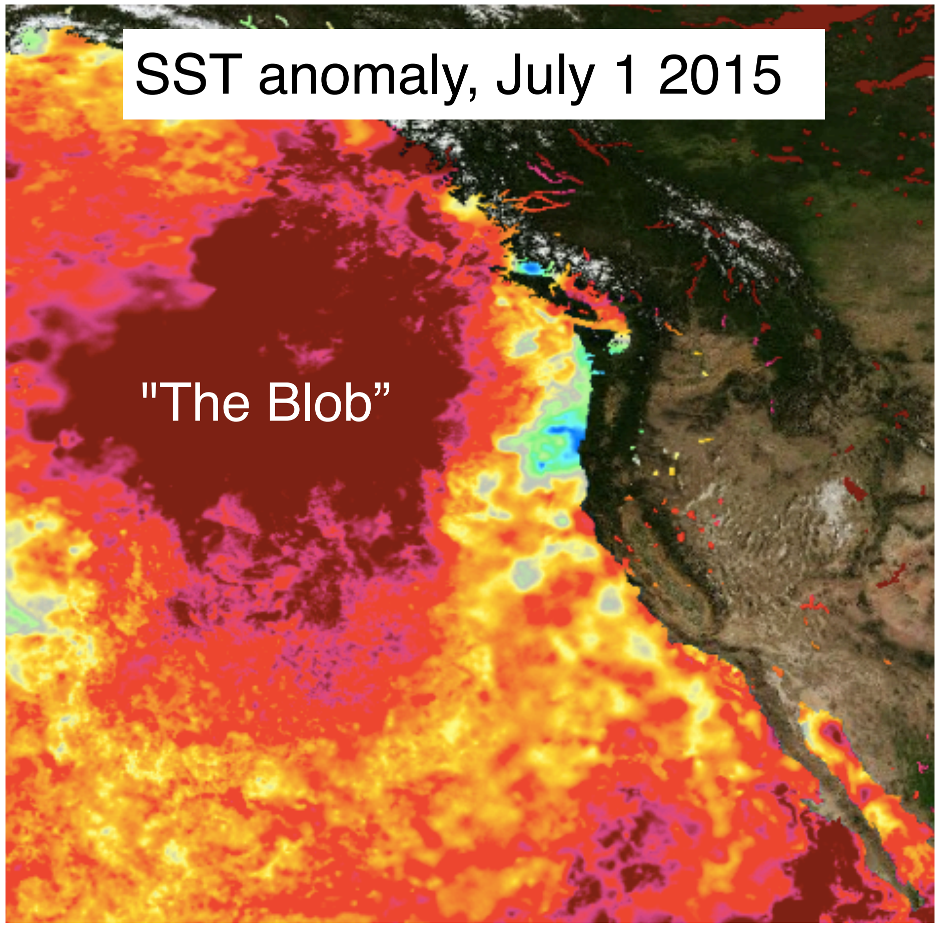
- **lack of understanding of regional variations prevents accurate prediction** (Jacox et al., 2019)

Linear trends in the yearly frequency of extreme hot days, 1982–2010

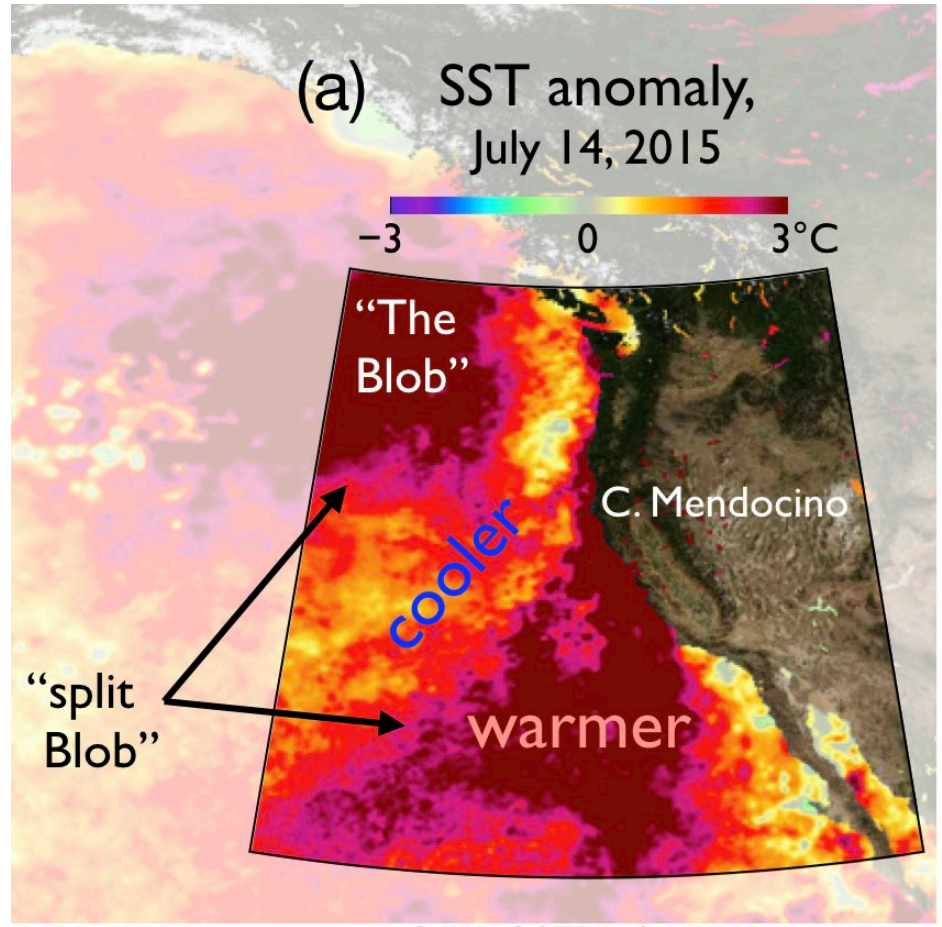


- California Current System: productive fisheries severely affected by MHWs

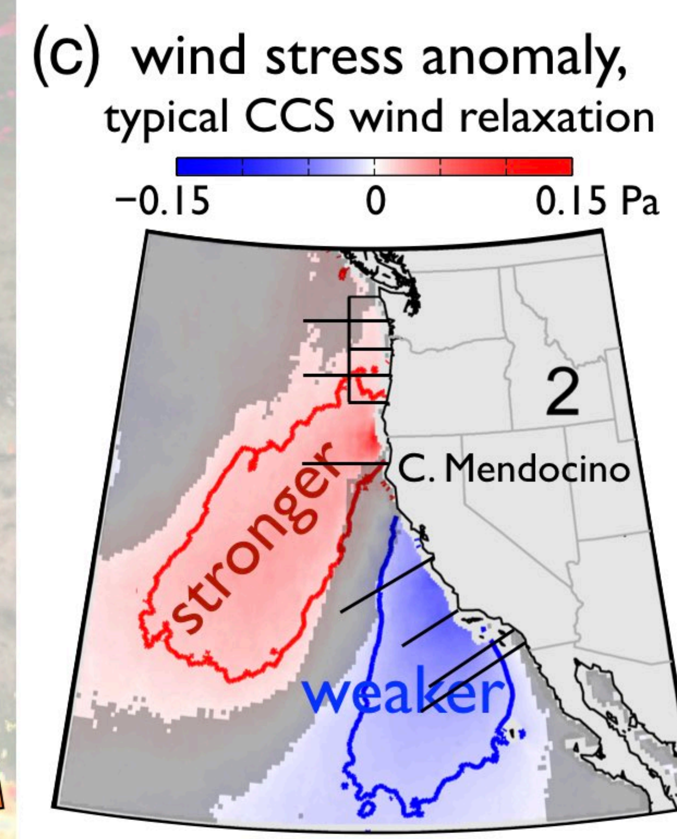
The spatial structure of a "split" SST anomaly in 2015 MHW is very similar to a known wind stress pattern.



GHRSST L4 MUR



GHRSST L4 MUR

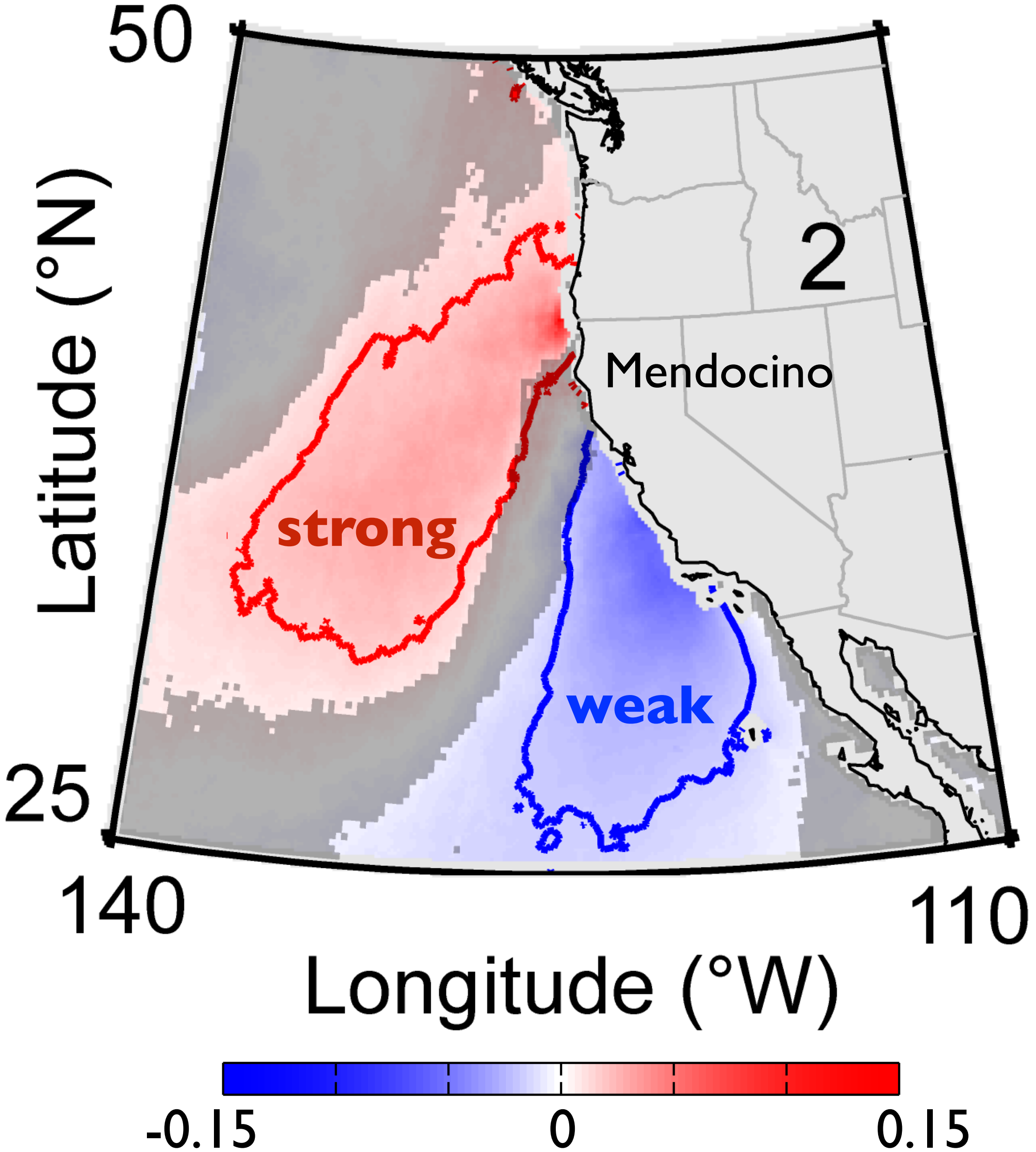


Fewings et al. JGR 2016

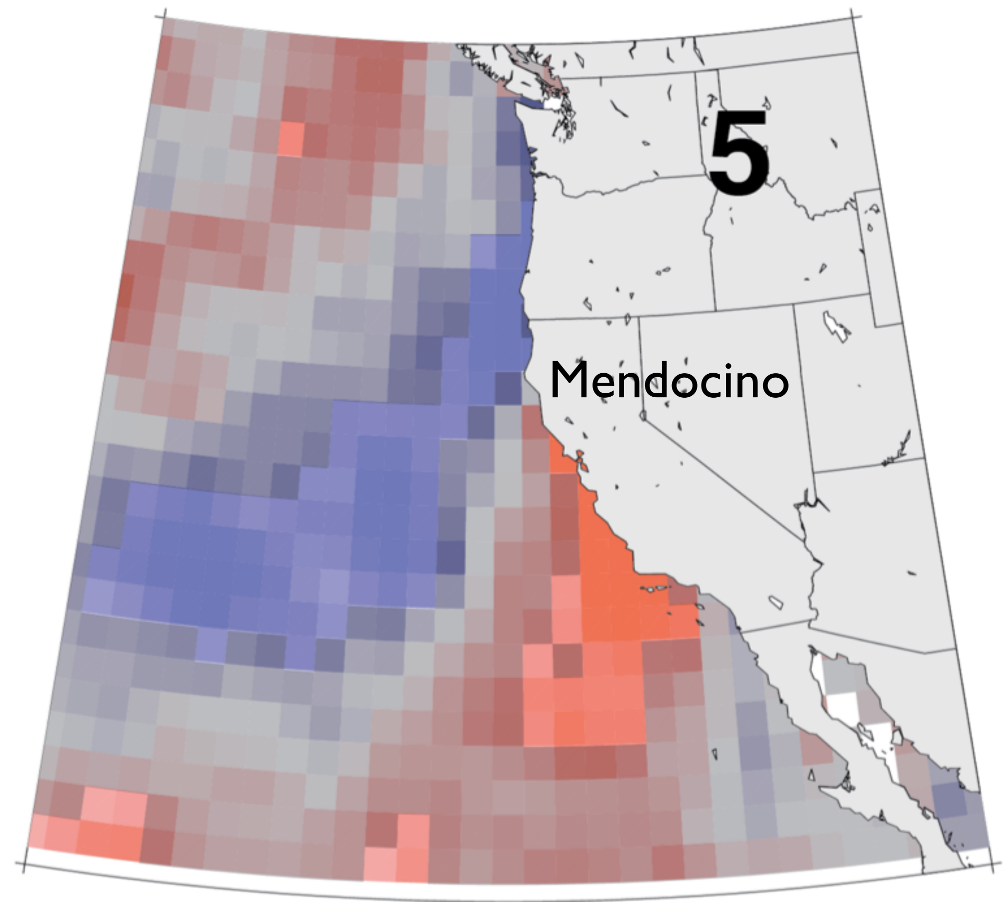
- this phase of wind dipole caused by synoptic **ridging** (Nuss 2007)
- triangular shape from MBL hydraulics, coastline bend at Cape Mendocino (Edwards et al. 2002)

The typical wind fluctuations are associated with SST anomaly **trends**.

wind stress anomaly (Pa)
composite over 69 cenCal summer relaxations
from QuikSCAT satellite L2 swaths



change in SST
during 44 summer wind relaxations
from OAFlux

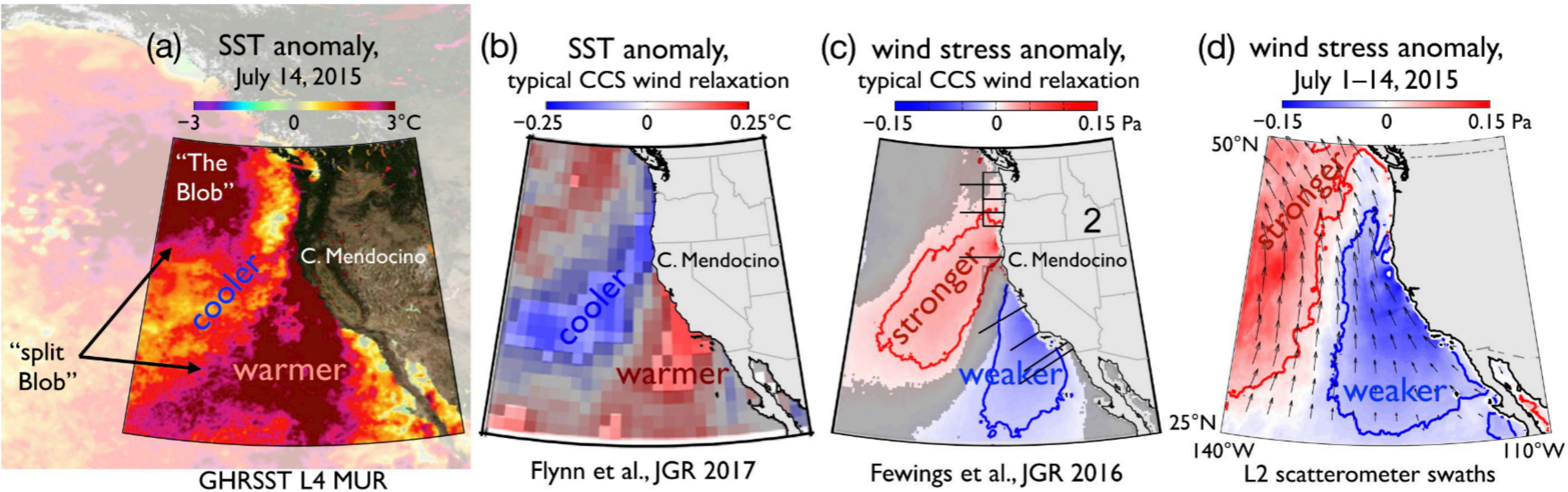


Kayla Flynn,
UConn M.S. 2016

Hypothesis: the SST pattern during extreme events (MHW) is due to a more persistent version of "normal" weather events.

Fewings et al. JGR 2016; Flynn, 2016; Flynn et al. JGR 2017

Using satellite SST, wind stress, and air-sea heat fluxes to understand the split MHW of 2015

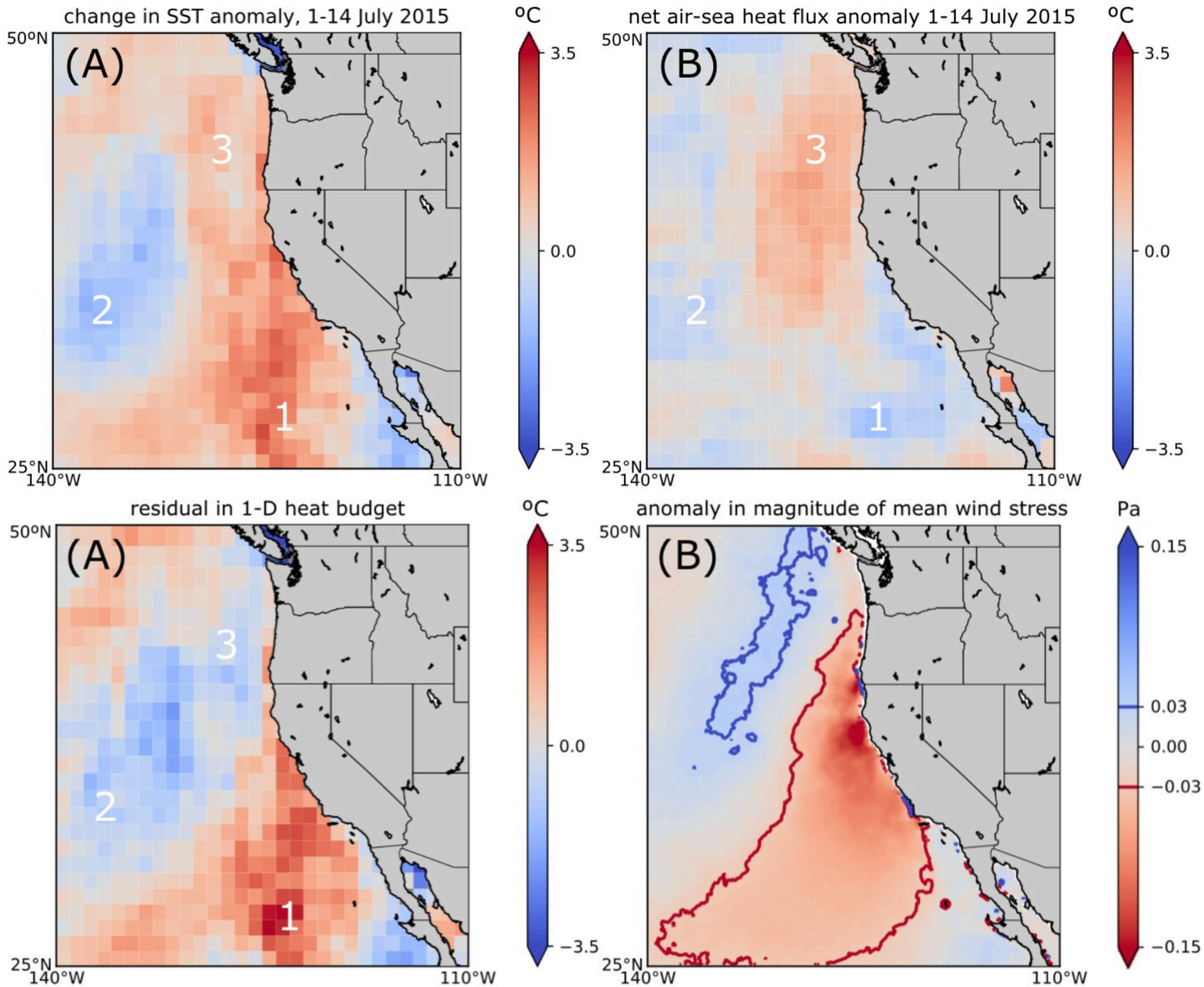


satellite SST GHRSST L4 MUR July 2015	satellite SST AMSR-E L2 44 events summer 2006-2009	satellite wind stress QuikSCAT L2 67 events summer 2000-2009	satellite wind stress QuikSCAT L2 RapidSCAT L2 ASCAT-A L2 July 2000-2017, July 2015

These spatial patterns are very similar.
To diagnose what caused the split MHW, next calculate terms in the heat budget

The SST anomaly is NOT explained by the air-sea heat flux anomaly

GHRSST L4 satellite SST



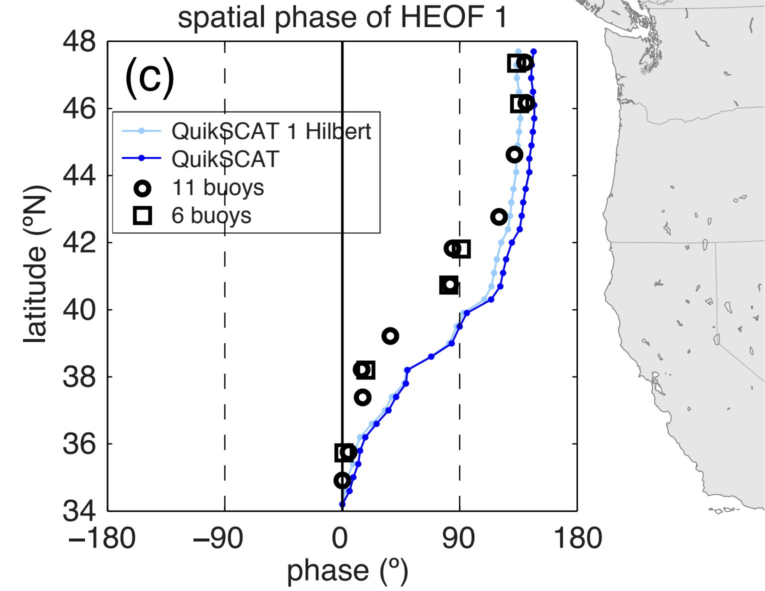
satellite air-sea heat fluxes: CERES, OAFlux, SeaFlux

satellite ocean vector wind stress: QuikSCAT, RapidSCAT, ASCAT-A L2

- where the ocean warmed off California, the air-sea heat flux anomaly was small due to +clouds
- weak winds off California can explain the split MHW (likely via changes in mixed layer depth and entrainment)
- "California wind relaxation" phase of wind dipole unusually persistent. Large-scale atmospheric ridging?
- similar to synoptic wind dipole events (Flynn et al. 2017)

Fewings and Brown, *Frontiers in Marine Science* 2019

Conclusions



WIND:

- In summer over the CCS,
  > half the wind velocity variance is coherent
  and captured by one HEOF **(NOAA weather buoys, QuikSCAT)**

MARINE HEAT WAVES:

- The split MHW of July 2015 was created by
  a persistent relaxation of the expansion fan winds off California **(satellite ocean vector winds)**
- Dipole SST anomaly added to pre-existing large-scale MHW **(satellite SST, air-sea heat flux)**

COASTLINE SHAPE:

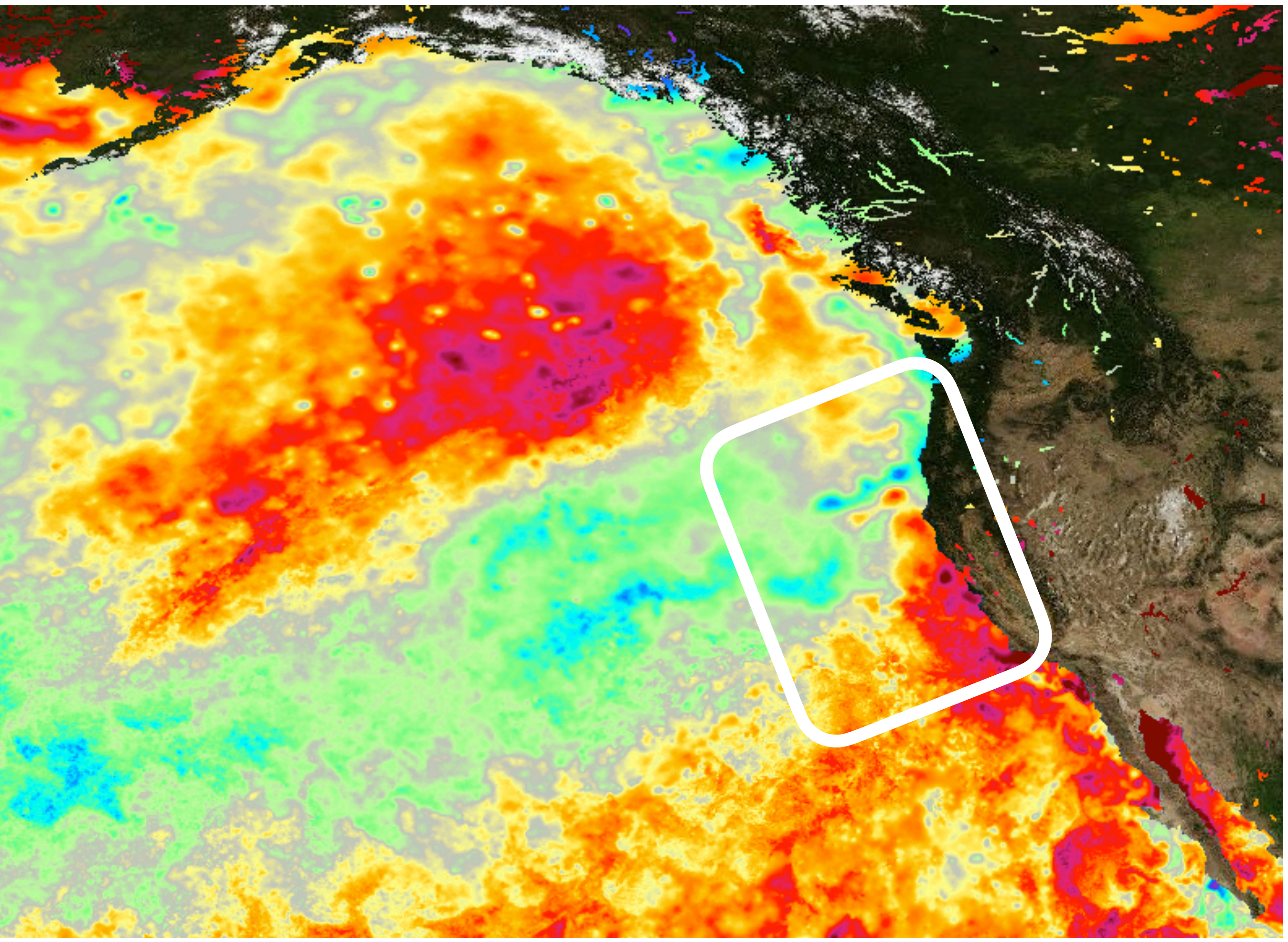
- The **offshore spatial structure** of the wind relaxations **(satellite wind speed)**
  is set by a hydraulic expansion fan from the coastline bend of CA (Edwards et al. 2002)
- Coastline shape and large-scale pressure pattern determines regional variations in MHW in the CCS

SO WHAT?

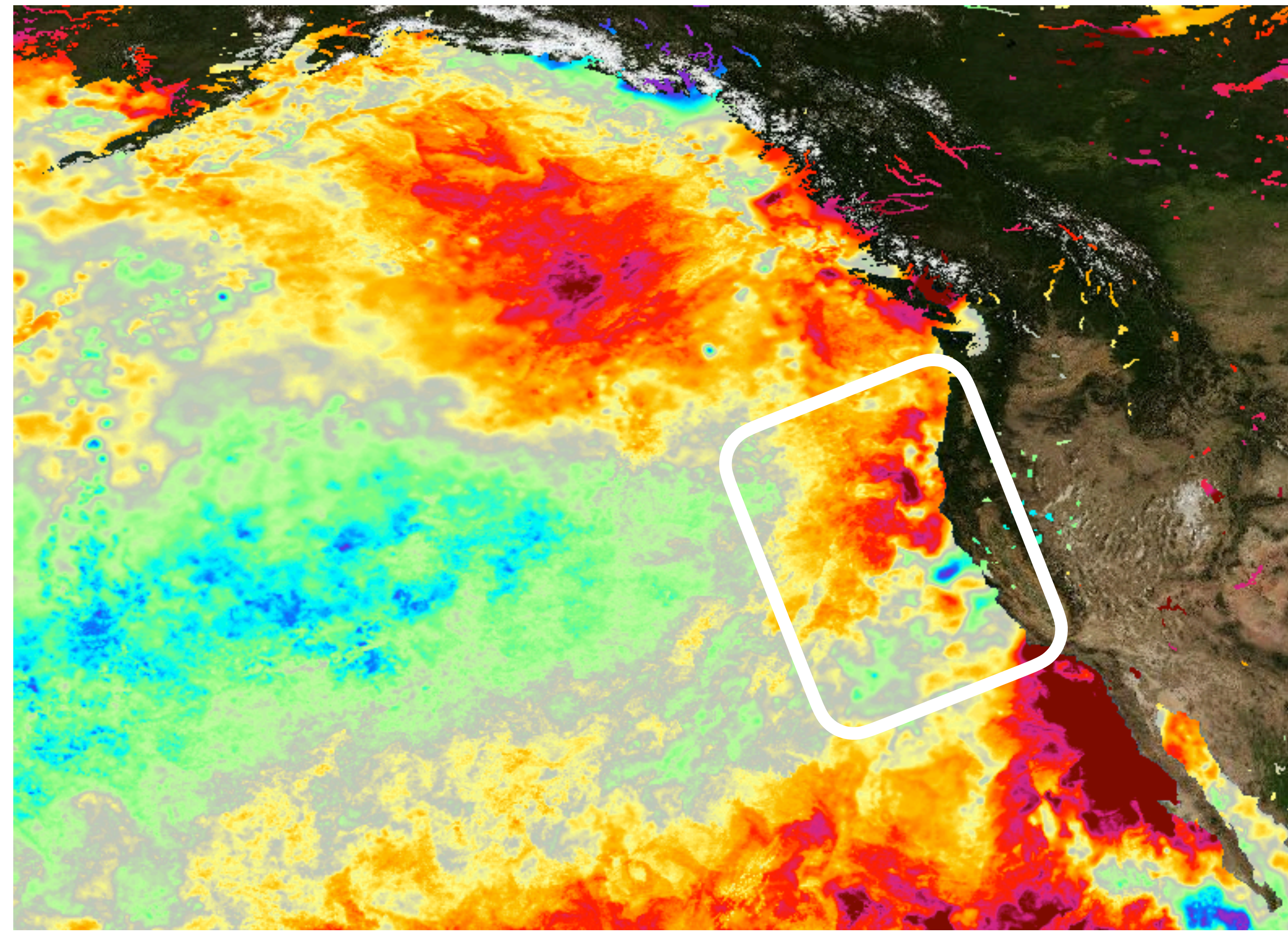
- The regional spatial variability of MHW in the CCS may be predictable… even if the timing is not.

Ongoing work (1): Other split MHWs?

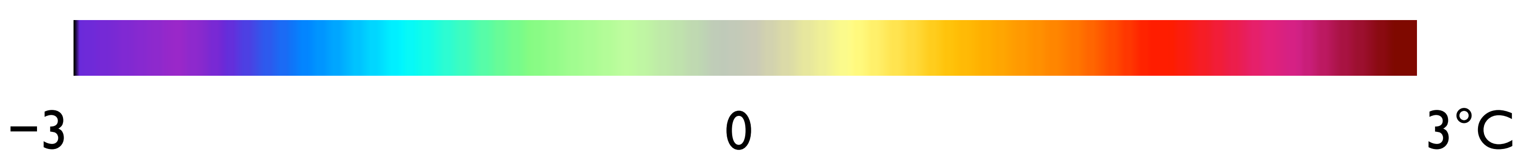
a split MHW
SST anomaly July 24, 2018



a split MHW with opposite wind dipole phase?
SST anomaly August 10, 2018



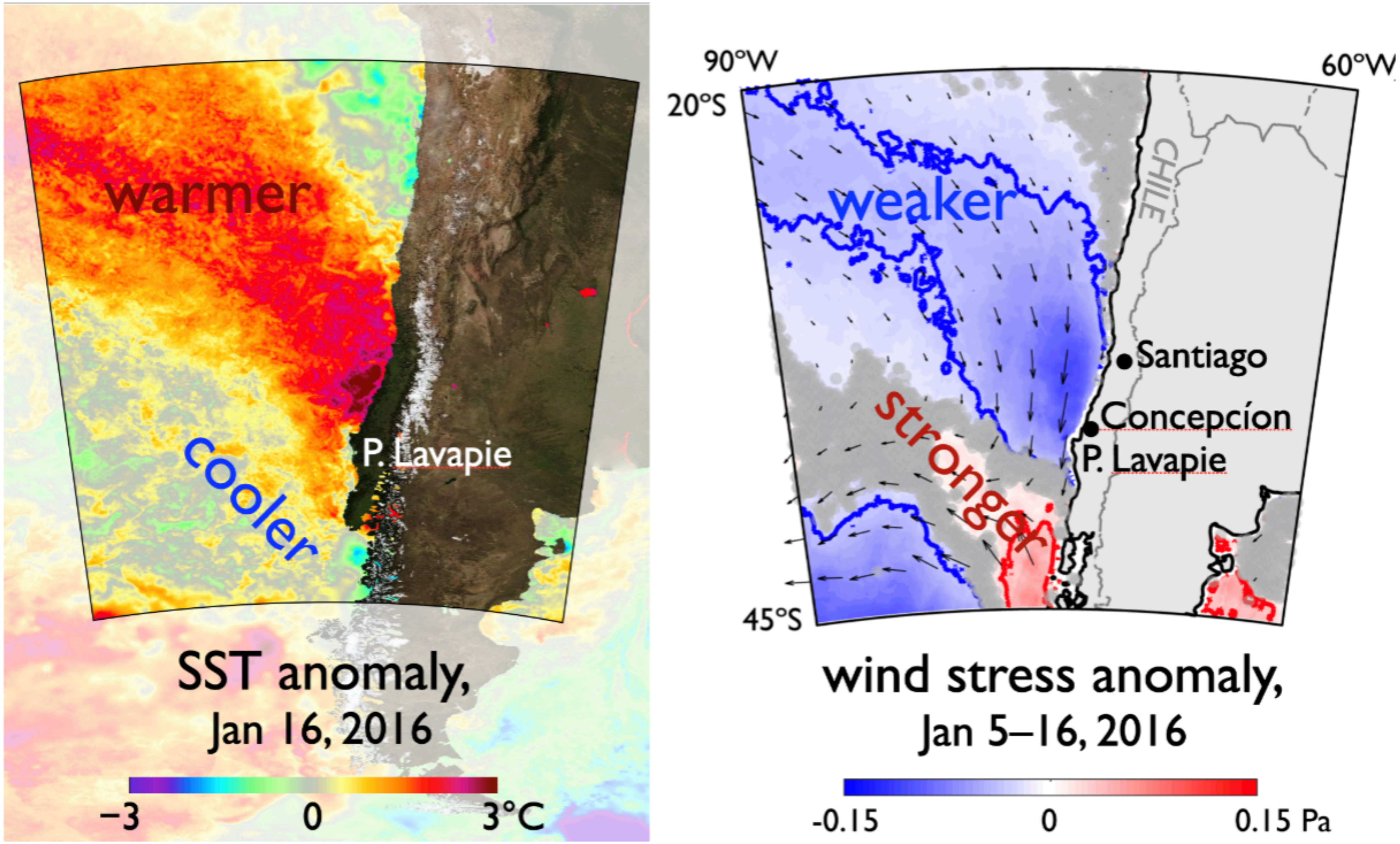
satellite SST: GHRSST L4 MUR



From NASA's State of the Ocean tool, http://podaac-tools.jpl.nasa.gov/soto

Gwen Larson, MS defense next week!

Ongoing work (2):
Similar wind-MHW relationship in Chile-Peru EBUS



(a) GHRSST L4 MUR

(b) L2 scatterometer swaths

Kylene Cooley, MS defense 4 weeks ago!

Cooley et al., *in prep*

Ongoing work (3):
Subsurface MHW structure

Newport Hydrographic Line, 1997-present

Shipboard CTD sections; 5 mooring programs

New gridded sections, robust climatologies, and **anomalies:**

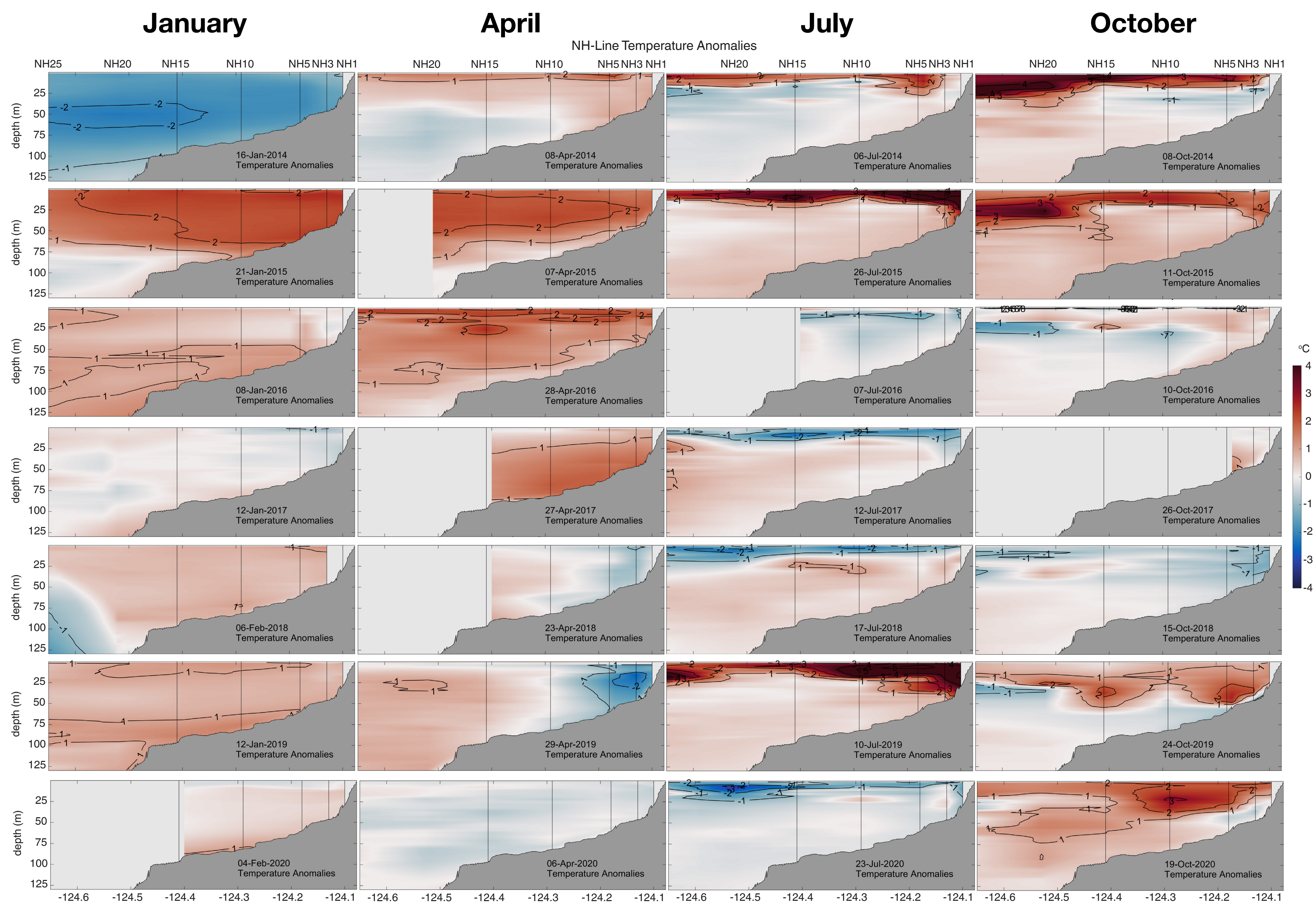


Figure by David Reinert, CEOAS/OSU

Risien et al., in prep. x2, Cervantes et al., in prep., Fewings et al., in prep.

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Wish lists

Observations:

(1) Higher resolution (space and time) global coverage **ocean mixed layer depth**
e.g. more Argo floats surfacing every 1-3 days not 10 days

(2) Higher-resolution, sub-daily, global coverage **air-sea heat fluxes** from satellites

(3) Higher-resolution satellite microwave SST (coverage near coast)

(4) Prevent gaps in in-situ time series

(5) How these new obs would play into management applications: improved near-surface conditions in data assimilative models —> high-resolution, >1 yr Lagrangian back trajectories for fisheries studies

Diversity and Inclusion:

(1) To have meaningful new engagement and partnerships, e.g. with indigenous communities, need longer timelines (6 months) between announcement of RFP priorities/LOI results and proposal deadlines

(2) More grad and postdoc fellowships targeted at underrepresented groups.
There's lots of data available to be analyzed! We need people time funded to do the analysis.

(3) Change reward systems to value D&I work more highly.